AN OPTIMAL LOAD SHEDDING SCHEME BASED ON THE ANALYTICAL HIERARCHY APPROACH: A CASE STUDY OF THE SELANGOR ELECTRICAL SYSTEM

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ABSTRACT

Most people depend on electrical energy in every aspect of their life. All sectors in Malaysia really need electrical energy to remain stable and consistent. As consumers, the public are want to have constant distributed of electricity energy without any disturbances. For example, food industries will be experiencing large financial lost if there are disturbances in electrical supplies even for only one day. If the total electrical load power demand greatly exceeds than the power supplied and no decision-making in removing a certain load, it will affect to the power system. Certain loads will be have to remove and needs some decision-making process in order to choose the best load(s) to be cut off. The load shedding process automatically detects overload conditions, then shed enough load to relieve the overloaded equipment before there is loss of generation, line tripping, equipment damage, or a chaotic random shutdown of the system. In this paper, an analysis is made to find the best method to be applied in load shedding. Analytical Hierarchy Process (AHP) and Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) is two methods most widely applied techniques MADM/MCDM problem. By using the AHP and TOPSIS methods, the priority of the load can be determined. This paper is focusing on the analysis of alternative methods in choosing the load priority of load shedding scheme in Selangor Electrical system. By using the AHP and TOPSIS methods, both have its own advantages in approach to determine the sequences of load to be shed.

ABSTRAK

Setiap manusia bergantung kepada tenaga elektrik dalam setiap aspek kehidupan mereka. Setiap sektor di Malaysia memerlukan bekalan yang stabil dan konsisten. Sebagai pengguna, ramai yang mahu bekalan sentiasa dibekalkan tanpa ada sebarang gangguan bekalan. Sebagai contoh, dari sudut industri permakanan, akan mengalami kerugian yang banyak biarpun tidak sampai sehari mengalami masalah bekalan elektrik. Jika permintaan bekalan tenaga dari pengguna melebihi bekalan tenaga yang dibekalkan dan tiada sebarang proses penumpahan beban dilakukan maka ia akan mendatangkan masalah pada sistem bekalan kuasa. Proses penumpahan beban ini secara automatik dapat mengesan keadaan lebihan beban, kemudian sebahagian beban akan digugurkan dan keputusan untuk memilih beban perlu diputuskan supaya tiada kehilangan janakuasa, terputus bekalan, kerosakan peralatan atau satu penutupan sistem yang tidak teratur. Melalui kajian ini, satu analisis dibuat bagi mencari kaedah terbaik untuk digunakan dalam proses penumpahan beban. Dengan menggunakan kaedah *Analytical Hierarchy Process (AHP)* dan *Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS)* iaitu dua kaedah ini digunakan secara meluas teknik MADM/MCDM dalam menentukan beban yang utama yang perlu ditumpahkan terlebih dahulu. Tesis ini akan fokus kepada menganalisis atau kaedah teori dalam menentukan beban yang perlu diberi keutamaan dalam skim penumpahan beban di Sistem Elektrik Selangor. Dengan menggunakan kaedah AHP dan TOPSIS ini, kedua-duanya mempunyai kelebihan masing-masing dalam mencari aturan beban yang perlu ditumpahkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

Σ	- Summation
N	- Number
Li	- Lower limit
ui	- Upper limit
CR	- Alternative
Mi	- Pairwise comparison ratio
Si	- Fuzzy synthesis extent
W	- Weight
Y,Z	- Column
kV	- Kilovolt
AHP	- Analytic Hierarchy Process
AP	- Area power
CI	- Consistency Index
CR	- Consistency ratio
GWh	- Giga watt hour
HV	- High voltage
Hz	- Hertz
LP	- Load power
LS	- Load Shedding
MCDM	- Multi Criteria Decision Making
MADC	- Multi Alternative Decision Making
MW	- Megawatt
MVA	- Megavolt ampere
MVAR	- Megavolt ampere reactive
NIS	- Negative Ideal Solution
OP	- Operating
OL	- Operating loads
PIS	- Positive Ideal Solution
PS	- Power Supply
RC	- Relative closeness coefficient

RI	- Random Index
S	- Apparent power
SCADA	- Supervisory Control and Data Acquisition
SEM	- Structural Equation Modeling
TOPSIS	- Technique for Order Preference by Similarity to Ideal Solution

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Power systems are designed and operated so that for any normal system condition, including a defined set of contingency conditions, there is adequate generating and transmission capacities to meet load requirements. However, there are economic limits on the excess capacity designed into a system and the contingency outages under which a system may be designed to operate satisfactorily. For those rare conditions where the systems capability is exceeded, there are usually processes in place to automatically monitor power systems loading levels and reduce loading when required. The load shed processes automatically sense overload conditions, then shed enough load to relieve the overloaded equipment before there is loss of generation, line tripping, equipment damage, or a chaotic random shutdown of the system.

In another word, load shedding occurs in places where the total electrical load power demand greatly exceeds the amount of power generated by the local power stations or national network power stations. Load shedding can be required when there is an imbalance between electricity demand (customers' usage) and electricity supply (the ability of the electricity network to generate and transport the required amount of electricity to meet this demand).

According to Perumal and Chan [3], load shedding priority is determined based on the criticality of loads, that is the least important loads are shed in the first stage and the very important ones are shed in the last stage. In another word, not all the loads were included in load shedding scheme, but only selected loads that full filled the load shedding design will be chosen.

In this thesis, the analysis outcome in interest is to remove loads by ranking them according to their priority. By earning the first rank means that the priority is less as the load shedding module aims is to unsure power continuity to only vital and most critical load in the system. Foremost the analysis is begin by setting a goal and identifies the criteria. And to aid or to simplify the selecting process comprising multiple criteria condition can be chosen from the variety multi-attribute (MADM) or multi criteria decision making technique (MCDM).

Analytical Hierarchy Process (AHP) and Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) is two methods most widely applied techniques MADM/MCDM problem. By using the AHP and TOPSIS methods, it can be determined the priority of the load. This thesis will focus to do the analysis or the theory of the alternative methods to choose the load priority in load shedding scheme in Selangor Electrical system.

1.2 Problem Statements

Allowing to the statistics provided by Suruhanjaya Tenaga from 2005-2008, the demand of the electric power was increasing year by year [2]. From the figure 1.1 shows the total electricity sales of Tenaga Nasional Berhad (TNB) for the year 2005 to 2008.

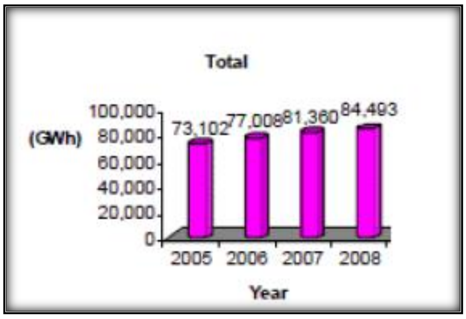

Figure 1.1: The total electricity sales (GWh) of TNB

The total electricity sales from 2005 to 2006 increased 5.34%, 5.65% from 2006 to 2007 and from 2007 to 2008 increased 3.85%. The sales increased 15.58% within three years of total electricity sales.

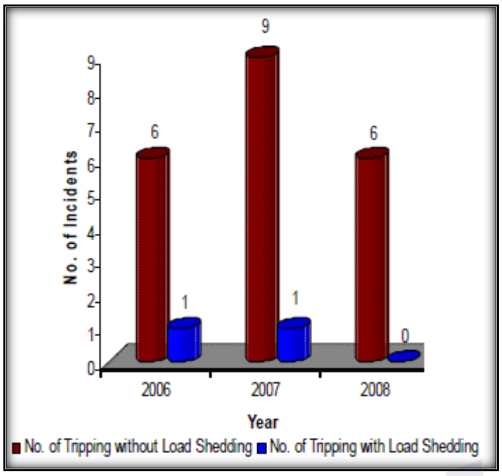

Figure 1.2: The number of transmission system tripping in Peninsular Malaysia with a load loss of 50 MW and above

Figure 1.2 shows the number of transmission system tripping in Peninsular Malaysia with a load loss of 50 MW and above for 2006 to 2008. Referring from the figure above can conclude that from 2006 only one incident with load shedding occur and six incidents of tripping without load shedding. One incident with load shedding and nine incidents of tripping without load shedding occurred in 2007. Six incidents of tripping occur in 2008 without load shedding and no incident with load shedding. Therefore, load shedding is important in reducing the incidence of tripping [2].

The electricity supply interruptions of the various causes such as natural disasters, equipment failures, overload, damaged by third parties, maintenance works, unknown, trees and others. The electricity Supply Company should take actions to maintain the distribution of the electricity supply of the unaffected area if the interruptions occurred and should reduce the interruptions as minimum as possible.

Most people depend on electrical energy in every aspect of their life. All sectors in Malaysia really need electrical energy to remain stable and consistent. As consumers, the public are want to have constant distributed of electricity energy without any disturbances. For example, food industries will be experiencing large financial lost if there are disturbances in electrical supplies ever for only one day.

A voluntary electricity load shedding schedule helps guarantee a resilient supply of needed power. This thesis will present a system with load shedding scheme for islanded power systems to overcome the problem during electricity interruptions.

1.3 Project objectives

There are three objectives for this project:

(a) To implement AHP and TOPSIS the multi criteria decision making methods
in the load shedding scheme/protection system.

(b) To justify a load shedding scheme for the power system.

1.4 Project scope

The system study was carried out using Microsoft Excel software application.

a) The system study carried out to rank load priority for load shedding scheme as one of defence scheme.

b) For this analysis, only power generated and load demand were taken into consideration.

CHAPTER 2

LITERATURE REVIEW

2.1 Load shedding

Load shedding is the term used to describe the deliberate switching off of electrical supply to parts of the electricity network, and hence to the customers in those areas. This practice is rare, but is a core part of the emergency management of all electricity networks. Load shedding can be required when there is an imbalance between electricity demand (customers' usage) and electricity supply (the ability of the electricity network to generate and transport the required amount of electricity to meet this demand) [4].

Load shedding technique is used to shut down certain predetermined electric loads or devices whenever there is any failure of generator to catch up the system frequency. When a power system is vulnerable to the stability problem, corrective control actions may be required [4]. The corrective controls can be done by restoring back the stable system when subjected to severe disturbances. Besides that, the corrective load shedding can also be applied if the subjected operation were units that cannot be shut down or the restoring of stable system could not effectively overcome the stability problem. As mentioned, the stability of a power system is important for an industry to keep their operation running.

It is normally used in industrial, large commercial and utility operations to make sure the system flow is always in good condition. The emergency loads shedding control required in restoring the power flow solvability and searching the minimum load shedding direction according to the sensitivity vector. This is one of the energy utilities' methods to maintain the stability on the energy generation system by temporary switching off the distribution of energy to different geographical areas.

2.2 Analytical Hierarchy Process (AHP)

AHP is a multi-criteria decision making methodology developed by Saaty [1] which has been widely used to address complex decisions. It is powerful and flexible in helping people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of pairwise comparison matrices, then synthesizing the results, AHP helps decision makers arrive at the best decision.

It involves building hierarchy (ranking) of decision elements and then making comparison between each possible pair in each cluster (as a matrix). This is gives a weighting for each element within a cluster (or level of the hierarchy) and also a consistency of ratio (useful for checking the consistency of the data).

In applying the AHP to a decision problem one structures the problem in a hierarchy with a goal at the top and then criteria (and often sub criteria at several levels, for additional refinement) and alternatives of choice at the bottom. The criteria can be subjective or objective depending on the means of evaluating the contribution of the elements below them in the hierarchy.

Furthermore, criteria are mutually exclusive and their priority or importance does not depend on the elements below them in the hierarchy. The number of alternatives should be reasonably small because there would then be a problem with improving the consistency of the judgments. It was observed that an individual cannot simultaneously compare more than seven objectives (plus or minus two) without becoming confused. Saaty [1] showed that the maximum number to compare should be no more than seven.

If the number of alternatives is more than seven, the rating mode of the AHP may be used. In the rating mode, in addition to the three general levels in a simple hierarchy of the objective, the criteria and the alternatives, an extra level above the alternatives consisting of intensities, which are refinements of the criteria governing the alternatives by creating a scale for each intensity, is included.

In short, when constructing hierarchies one must include enough relevant details to represent the problem as thoroughly as possible, but not so much as to include the whole universe in a small decision. One need to consider the environment surrounding the problem, identify the issues or attributes that one feels influence, contribute to the solution, and identify the participants associated with the problem. Arranging the goals, attributes, issues, and stakeholders in a hierarchy serves three purposes:

a) It provides an overall view of the complex relationships inherent in the situation.
b) It captures the spread of influence from the more important and general criteria to the less important ones.
c) It permits the decision maker to assess whether he or she is comparing issues of the same order of magnitude in weight or impact on the solution.

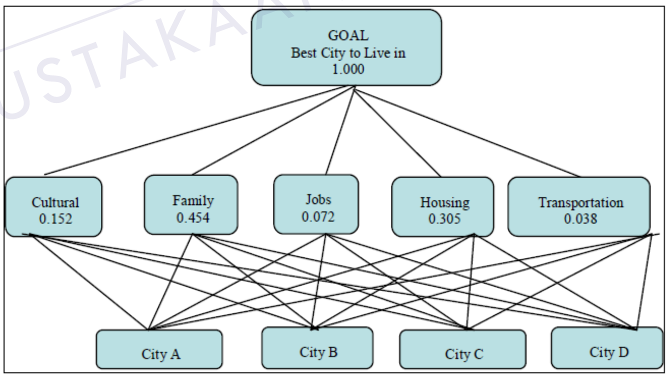

Figure 2.1: Relative model for choosing best city to live in.

For example consider a decision such as to choose the best city in which to live shown in figure 2.1. The figure shows how to make this decision using relative measurement method of the AHP. The criteria are pairwise compared with respect to the goal, the alternatives are pairwise compared with respect to each criterion and the results are synthesized or combined using a weighting and adding process to give an overall ranking of the alternatives.

An AHP hierarchy has at least three levels as a figure 2.1:

a) Level-1: The main objective or goal of the problem at the top.

b) Level-2: Multiple criteria that define alternatives in the middle.

c) Level-3: Competing alternatives at the bottom

The applications of this powerful management science tool include project management, environment policy, information systems, risk assessment, project screening and hidden failures [4]. The advantages using AHP method is:

a) The advantages of AHP over other multi criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies [6] generally; users find the pairwise comparison form of data input straightforward and convenient.
b) Additionally, the AHP method has the distinct advantage that it decomposes a decision problem into its constituent parts and builds hierarchies of criteria. Here, the importance of each element (criterion) becomes clear [7]
c) AHP helps to capture both subjective and objective evaluation measures. While providing a useful mechanism for checking the consistency of the evaluation measures and alternatives, AHP reduces bias in decision making.
d) The AHP method supports group decision−making through consensus by calculating the geometric mean of the individual pairwise comparisons [8].
e) AHP is uniquely positioned to help model situations of uncertainty and risk since it is capable of deriving scales where measures ordinarily do not exist [9]

In this thesis we have used the following steps of AHP to help us to measure the relative importance of the weight values of several criteria. The basic procedure to carry out the AHP consists of the following steps:

a) List the overall goal, criteria and decision alternatives
b) Develop a pairwise comparison matrix.
c) Develop a normalized matrix.
d) Develop the priority vector.
e) Rank the preferred criteria

2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS (technique for order performance by similarity to ideal solution) is a useful technique in dealing with multi attribute or multi-criteria decision making (MADM/MCDM) problems in the real world [10]. TOPSIS known as one of the most classical MCDM methods, was first developed by Hwang and Yoon [11], is based on the idea that the chosen alternative should have the shortest distance from the Positive Ideal Solution (PIS) and on the other side the farthest distance of the Negative Ideal Solution (NIS). The Positive Ideal Solution maximizes the benefit criteria and minimizes the cost criteria, whereas the Negative Ideal Solution maximizes the cost criteria and minimizes the benefit criteria [12, 13].

This method is a unique technique to identify the ranking of all alternatives considered. It helps decision maker(s) (DMs) organize the problems to be solved, and carry out analysis, comparisons and rankings of the alternatives. Accordingly, the selection of a suitable alternative(s) will be made.

The basic idea of TOPSIS is rather straightforward. It originates from the concept of a displaced ideal point from which the compromise solution has the shortest distance [14, 15]. According to Kim et al. [16] and our observations, four TOPSIS advantages are addressed:

a) a sound logic that represents the rationale of human choice;
b) a scalar value that accounts for both the best and worst alternatives simultaneously;
c) a simple computation process that can be easily programmed into a spread sheet;

d) the performance measures of all alternatives on attributes can be visualized on a Polyhedron, at least for any two dimensions.

In recent years, TOPSIS has been successfully applied to the areas of human resources management [17], transportation [18], product design [19], manufacturing [20], water management [21], quality control [22], and location analysis [23]. In addition, the concept of TOPSIS has also been connected to multi-objective decision making [24] and group decision making [25]. The high flexibility of this concept is able to accommodate further extension to make better choices in various situations. In the process of TOPSIS, the performance ratings and the weights of the criteria are given as exact values. The steps of TOPSIS model are as follows:

a) Calculate the normalized decision matrix.
b) Calculate the weighted normalized decision matrix.
c) Determine the Positive Ideal Solution and Negative Ideal Solution.
d) Calculate the separation measures for each alternative from the positive and negative ideal solution.
e) Calculate the relative closeness to the ideal solution for each alternative.
f) Rank the preference order

To clarify its features, the characteristics of TOPSIS and AHP [26] are compared in Table 2.1. We can see that the major weaknesses of TOPSIS are in not providing for weight elicitation, and consistency checking for judgments. However, AHP's employment has been significantly restrained by the human capacity for information processing, and thus the number seven plus or minus two would be the ceiling in comparison [27]. From this viewpoint, TOPSIS alleviates the requirement of paired comparisons and the capacity limitation might not significantly dominate the process.

Characteristics	AHP	TOPSIS
Category	Cardinal information, information on attribute, MADM	Cardinal information, information on attribute, MADM
Core process	Pairwise comparison (cardinal ratio measurement)	The distances from PIS and NIS (cardinal absolute measurement)
Attribute	Given	Given
Weight elicitation	Pairwise comparison	Given
Consistency check	Provided	None

Table 2.1: Comparison of characteristics between AHP and TOPSIS

The uniqueness of AHP and TOPSIS in handling a situation with many criteria to consider to makes these techniques the best method in offering an alternative to a load shedding scheme. Load shedding scheme is also a situation that has more than one criterion to consider upon before deciding which load to be shed according. AHP and TOPSIS not only capable of offering the ideal alternative load shedding scheme but also these following features.

CHAPTER 3

METHODOLOGY

In order to resolve cases related to an alternative or criteria selection problems (MADM/MCDM) problems), various methods have been applied. Many methods are used to solve the MCDM problems, which sometimes give different results. To resolve MCDM problem, we can use AHP and TOPSIS methods. The advantages of AHP method are it can provide solutions through the analysis of quantitative and qualitative decision. In addition, it presented simple solution using hierarchical model. On the other hand, TOPSIS method gives a simple concept and is easy to implement, computationally efficient, and easy to be understood.

3.1 Analytic Hierarchy Process Algorithm

Various forms of AHP are available in research works nowadays. However, this thesis will use the form which is introduced by Dr. Thomas L. Saaty[1]. The way in finding the pair wise comparison values is differs with other versions of AHP analysis. Some other methods are using the normalized pair wise comparison values within the matrices. The corresponding weights are obtained from the average values in each row. However, this thesis emphasized on getting the *n*th root of product of the pair wise comparison value in each row of the matrices and then normalizes the aforementioned *n*th root of products to obtain the corresponding weights and ratings.

3.1.1 AHP ALGORITHM

Step 1: Develop the weights for criteria

Develop a single pair wise comparison matrix for the criteria. For this paper, the ratio between criteria is obtained.

$$\begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ A_C = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} & \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}, i = 1,2,\ldots n, \; j = 1,2,\ldots n \tag{3.1}$$

Where C_1, C_2 …….,Cn representing the criteria
aij represent the rting of Ci with respect to Cj

Multiplying the values in each row to obtain the *n*th root of product and find the total root of product in whole system.

$$n^{th} \text{ root of product} = \sqrt[n]{product\ of\ each\ row} \tag{3.2}$$

where n is the positive integer number

Normalizing the nth root of product to get the appropriate weights

$$\text{Weight} = \frac{n^{th} root\ of\ product}{\sum(n^{th}\ root\ of\ product)} \tag{3.3}$$

Calculate the Consistency Ratio (CR) with the aid of Random Index (RI) and CR must be less than 0.1 to make sure the result is reliable. If CR exceeds 0.1, the adjustments of the pair wise values need to be done.

$$\text{CR} = \frac{CI}{RI} \tag{3.4}$$

Where Σ column is the summation of pair wise values for each alternative vertically. RI is direct function of the number of alternatives or system being considered and is given as:

N	1	2	3	4	5	6	7	8	9	10
IRI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3.1: Random number of R1

Where the value Consistency Index (CI) can be found by using this equation

$$CI = \frac{Lambda\_Max - n}{n-1} \tag{3.5}$$

Step 2: Develop the rating for each alternative in each criterion

The process is the same as in Step 1. However, the single pair wise comparison matrix must be done for each criterion individually.

Step 3: Calculate the overall weights and determine the priority

The final score for each alternative is the summation of the product of criterion to alternative.

There will be *n* number of overall weight and *n* must be an integer that does not exceed 39.

$$Final\_score_{\text{alternative } X} = (\text{Criterion A} \times \text{Alternative X}) + (\text{Criterion B} \times \text{Alternative X}) + (\text{Criterion C} \times \text{Alternative X}) + \ldots\ldots\ldots + (\text{Criterion I} \times \text{Alternative X}) \tag{3.6}$$

Where Criterion A = 1st criterion, Criterion B = 2nd Criterion ……. Criterion I = 39th Criterion and $1 \le X \le 39$

The highest of the score shows the preceding load to be shed if compared with others. The methodology can be simplified by using flowchart as shown in Figure 3.1

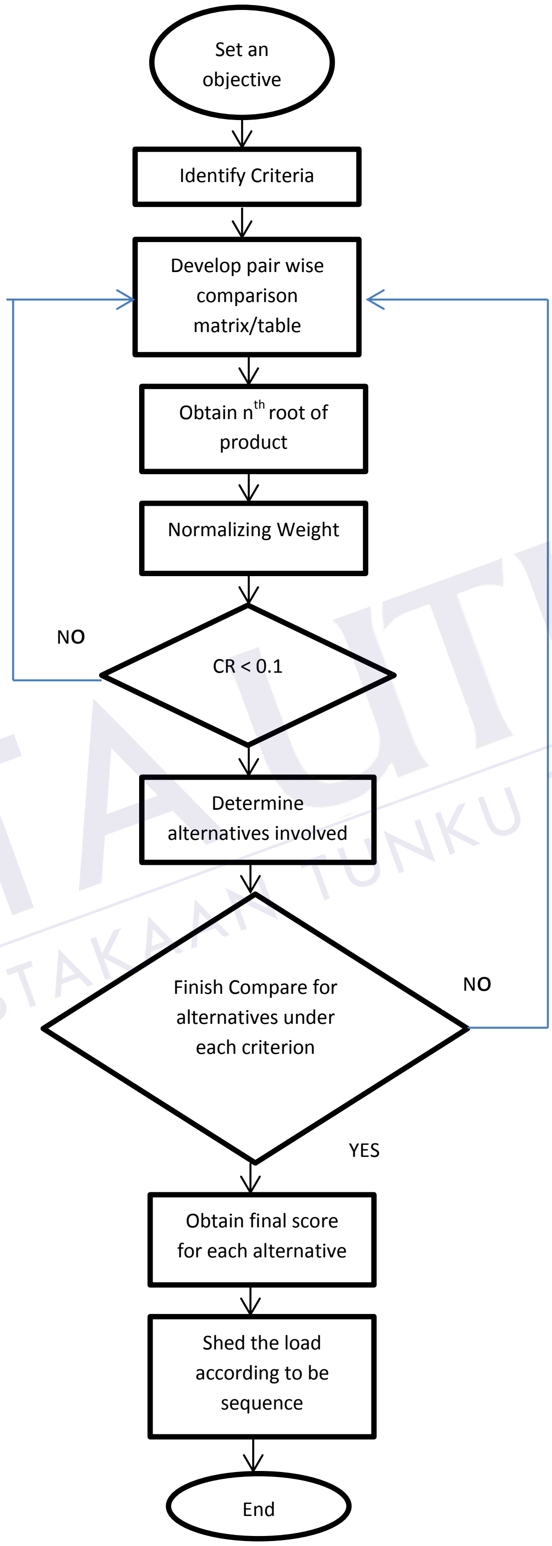

Figure 3.1: Flowchart for AHP Method

3.2 TOPSIS Process Algorithm

TOPSIS method is applied to give rank according to the importance of the alternative towards the criteria's throughout the specific calculation. With this method, operators could base on the ranking provided and solve the tripping problem without causing the whole system to shut down and collapse.

STEP 1: Establish the decision matrix

Create the decision matrix for the analysis. The decision matrix consisting of m alternative and n criteria with the intersection of each alternative and criteria given as Xij. Then form a matrix $(Xij)_{mxn}$ for analysis purposed.

$$\text{Alternative} = \begin{bmatrix} \text{PLKG\_U1} \\ \text{PLKG\_U3} \\ \text{PLKG\_U2} \\ \text{PGPS\_U1} \\ \text{PGPS\_U2} \\ \text{MPSSST} \\ \text{MPSSGT1} \\ \text{MPSSGT2} \\ \text{CBPSGT3} \end{bmatrix} \tag{3.7}$$

$$\text{Criteria (Xij)} = \begin{array}{c} \begin{array}{cc} \text{Operating Load} & \text{Area Power} \end{array} \\ \begin{bmatrix} \text{PLKG\_U1} & \text{PLKG\_U1} \\ \text{PLKG\_U3} & \text{PLKG\_U3} \\ \text{PLKG\_U2} & \text{PLKG\_U2} \\ \text{PGPS\_U1} & \text{PGPS\_U1} \\ \text{PGPS\_U2} & \text{PGPS\_U2} \\ \text{MPSSST} & \text{MPSSST} \\ \text{MPSSGT1} & \text{MPSSGT1} \\ \text{MPSSGT2} & \text{MPSSGT2} \\ \text{CBPSGT3} & \text{CBPSGT3} \end{bmatrix} \end{array} \tag{3.8}$$

STEP 2: Normalized the decision matrix

The decision matrix is then normalized by using normalization method using the equation below:

$$Rij = \frac{Xij}{\sqrt{[\Sigma_{Xij}\,2]}}$$

(3.9)

Where;

Xij represent the intersection of each alternative and criteria

Rij represent the normalized the intersection of each alternative and criteria

i = 1, 2, 3…… m; j: 1, 2, 3 …… n

STEP 3: Weight normalized decision matrix is constructed

$$Vij = Wj \times Rij \tag{3.10}$$

Rij = represent the decision matrix

Wij = represent the weight matrix

i = 1, 2, 3…… m; j: 1, 2, 3 …… n

STEP 4: Positive and negative ideal solution is determined

Identifying the positive ideal alternative and negative ideal alternative. Let J be the set of benefit criteria and J' be the set of non-benefit criterion.

Positive Ideal Solution (PIS)

$$PIS = \{v_1^*, \ldots, v_n^*\}$$

where $v^* = \{\max(v_{ij}) \text{ if } j \in J; \min(v_{ij}) \text{ if } j \in J'\}$

(3.11)

Negative Ideal Solution (NIS)

$$NIS = \{v_1',\ldots, v_n'\}$$
$$\text{where } v' = \{\min (v_{ij}) \text{ if } j \in J;\ \max (v_{ij}) \text{ if } j \in J'\}$$

(3.12)

STEP 5: The distance of each alternative determined

The distance of each alternative can be determined by using equation below for Positive Ideal Solution and Negative Ideal Solution

S of each alternative from the PIS is given as:

$$\sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^{+}\right)^2}\ ,\ \ i = 1,\ldots,m$$

(3.13)

Similarly, the separation measure SN of each alternative from the NIS is as follows:

$$\sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^{-}\right)^2}\ ,\ \ i = 1,\ldots,m$$

(3.14)

STEP 6: The relative closeness to ideal reference point is calculated

Relative Closeness (RC) can be found using equation below

$$RC = \frac{SN}{S+SN}$$

(3.15)

Where

S = Positive Ideal Solution

SN = Negative Ideal Solution

STEP 7: The Ranking of alternative is determine

Finally the results can be rank from largest to the smallest where the largest value is the less priority whereas the smallest value is the most important. The step can be simplified as shown step by step flowchart to brief the TOPSIS method

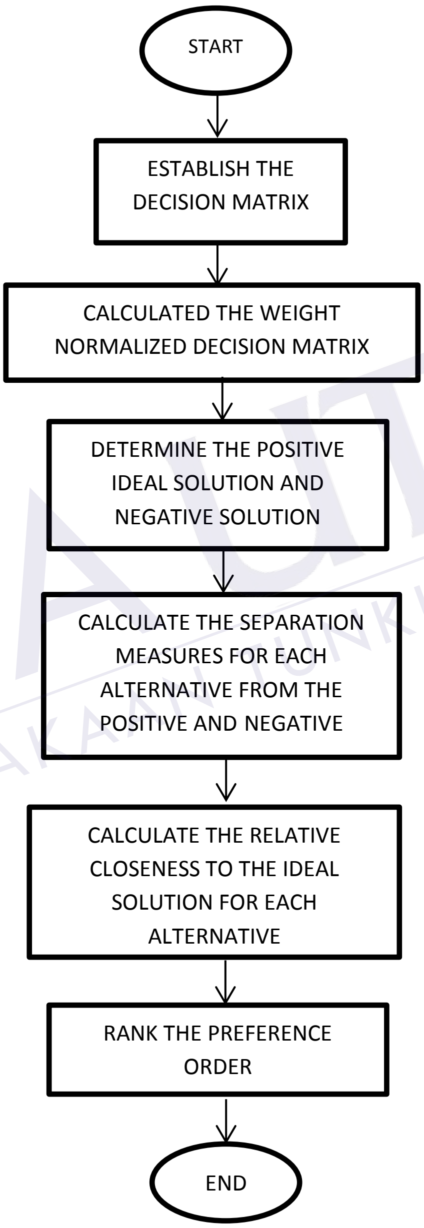

Figure 3.2: Flowchart for TOPSIS method

CHAPTER 4

RESULT AND ANALYSIS

4.1 Load Shedding Scheme in Selangor Electrical System

An analysis for the Selangor load shows system is completed using the AHP method. There are thirty nine buses from Selangor systems were selected for the analysis. The criteria for this analysis are operating load and area power. The table below shows the information used in AHP analysis

NO	BUS NAME	OPERATING LOAD	AREA POWER
1	MPSSGT1	90.233	106.585
2	MPSSGT2	90.111	105.575
3	MPSSST	90.216	110.609
4	PKLG_U1	1.539	304.344
5	PKLG_U2	1.539	203.180
6	PKLG_U3	1.656	271.801
7	PGPS_U1	73.445	119.568
8	PGPS_U2	73.921	118.576
9	CBPSGT3	0.548	104.304
10	CEND_U1	6.746	7.006
11	CEND_U2	6.791	7.006
12	CEND_U3	6.791	7.006
13	TMGR_U1	16.163	46.821
14	SYPS_U1	0.341	19.050
15	PGAU	14.912	21.483

NO	BUS NAME	OPERATING LOAD	AREA POWER
16	KNRG_U3	8.108	12.849
17	KNYR_U1	40.706	79.345
18	SYPS_U2	0.354	11.020
19	KNYR_U3	42.228	93.145
20	KNYR_U4	40.855	80.325
21	LPIA_U1	23.181	25.132
22	SYPS_	0.345	1.050
23	PAKAGTIA11.5	84.792	16.102
24	PAKAGTIB11.5	85.787	16.004
25	PAKASTIC12.0	91.758	15.814
26	PAKAGT2A11.5	81.809	16.370
27	PAKAGT2B11.5	83.798	16.186
28	PAKAST2C12.0	88.773	16.098
29	PAKAGT3A11.5	11.080	11.500
30	PAKAGT3B11.5	10.930	11.500
31	PAKAST3C12.0	11.010	12.000
32	PAKAGT4A10.5	66.790	10.523
33	PAKAGT4B10.5	81.565	10.778
34	PAKAST4C10.5	42.503	10.630
35	SIHY_U1	0.162	3.147
36	SIHY_U2	0.162	3.147
37	SIHY_U3	0.162	35.152
38	SYPS_U4	0.548	1.050
39	PENGGT1	63.249	96.951
	TOTAL	1435.607	2158.732

Table 4.1: The information of Selangor Electrical System

4.1 AHP ANALYSIS RESULT

Step 1: Develop the weights for criteria

A single pair wise comparison matrix for the criteria is developed. The ratio of total operating load to the total of area power is;

	O.LOAD	AREA
O.LOAD	1.000	0.665
AREA	1.503	1.000

Table 4.2 Pair wise comparison table for criteria

As in Table 4.2, there are two criteria needed to be considering in order achieving the goal. Thus, the number of root, *n*=2.

Afterward, the values in each row were multiplied to obtain the n^{th} root of product and the total root of product in whole system is found

$$n^{th}\ root\ of\ product = \sqrt[n]{product\ of\ each\ row}$$

(4.1)

	O.LOAD	AREA	R.O.P
O.LOAD	1.000	0.665	0.815
AREA	1.503	1.000	1.226

Table 4.3: The root of product of criteria

Then, the nth root of product to get the appropriate weights is normalized using the following formula

$$\text{Weight} = \frac{n^{th} root\ of\ product}{\sum(n^{th}\ root\ of\ product)}$$

(4.2)

	O.LOAD	AREA	R.O.P	WEIGHT
O.LOAD	1.000	0.665	0.815	0.399
AREA	1.503	1.000	1.226	0.601
TOTAL	2.503	1.665	2.042	1.000

Table 4.4: Priority Vector /Weight

Moreover, the Consistency Ratio (CR) is calculated with the aid of Random Index (RI) and CR must be less than 0.1 to make sure the result is reliable. If CR exceeded 0.1, the adjustments of the pair wise values need to be done

$$\text{CR} = \frac{\text{CI}}{\text{RI}}$$

(4.3)

$$\text{CI} = \frac{\text{Lambda\_Max} - \text{n}}{\text{n} - 1}$$

(4.4)

$$Lambda\_Max = \sum(\sum column_{each\ alternative} \times weight_{per\ row})$$

(4.5)

where $\sum column$ is the summation of pair wise values for each alternative vertically. RI is direct function of the number of alternatives or system being considered and is given as:

Size of matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 4.5: Random Index

n	16	17	18	19	20	21	22	23
λ_{max}	39.9676	42.7375	45.5074	48.2774	51.0473	53.8172	56.5872	59.3571
RI	1.5978	1.6086	1.6181	1.6265	1.6341	1.6409	1.6470	1.6526
	24	25	26	27	28	29	30	31
	62.1270	64.8969	67.6669	70.4368	73.2067	75.9767	78.7466	81.5165
	1.6577	1.6624	1.6667	1.6706	1.6743	1.6777	1.6809	1.6839
	32	33	34	35	36	37	38	39
	84.2864	87.0564	89.8263	92.5962	95.3662	98.1361	100.9060	103.6759
	1.6867	1.6893	1.6917	1.6940	1.6962	1.6982	1.7002	1.7020

Table 4.6: The λ max and random index for dimensions greater than 15.

Value CR is must less than 0.10, therefore the consistency of the judgments matrix was found to be within acceptable tolerance. But if the consistency ratio is greater than 0.10, subjective judgments will be revised.

	O.LOAD	AREA	R.O.P	WEIGHT
O.LOAD	1.000	0.665	0.815	0.399
AREA	1.503	1.000	1.226	0.601
TOTAL	2.503	1.665	2.042	1.000
SUM*PV	1.000	1.000		
λmax	2.000			
CI	0.000			
CR	0.000			

Table 4.7: Value of λmax

The weights among the criteria, *Wc* is given by:

$$W_C = \begin{bmatrix} \text{Weight for operating load} \\ \text{Weight for area power} \end{bmatrix} \tag{4.6}$$

$$\text{Wc} = \begin{bmatrix} 0.399 \\ 0.601 \end{bmatrix}$$

we know that Area Power much more importance that operating load

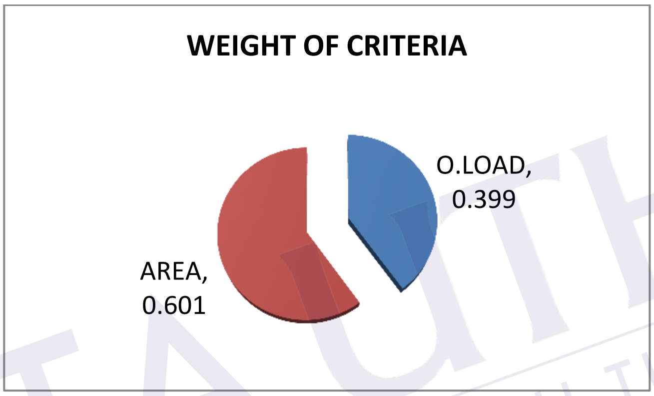

Figure 4.1: Weight of Criteria

Step 2: Develop the rating for each alternative for each criterion

BUS	MPSSGT1	MPSSGT2	MPSSST	PKLG_U1	PKLG_U2	PKLG_U3	PGPS_U1	PGPS_U2	CBPSGT3	CEND_U1	CEND_U2	CEND_U3	TMGR_U1	SYPS_U1	PGAU
MPSSGT1	1.000	1.001	1.000	58.631	58.631	54.489	1.229	1.221	164.659	13.376	13.287	13.287	5.583	264.613	6.051
MPSSGT2	0.999	1.000	0.999	58.552	58.552	54.415	1.227	1.219	164.436	13.358	13.269	13.269	5.575	264.255	6.043
MPSSST	1.000	1.001	1.000	58.620	58.620	54.478	1.228	1.220	164.628	13.373	13.285	13.285	5.582	264.563	6.050
PKLG_U1	0.017	0.017	0.017	1.000	1.000	0.929	0.021	0.021	2.808	0.228	0.227	0.227	0.095	4.513	0.103
PKLG_U2	0.017	0.017	0.017	1.000	1.000	0.929	0.021	0.021	2.808	0.228	0.227	0.227	0.095	4.513	0.103
PKLG_U3	0.018	0.018	0.018	1.076	1.076	1.000	0.023	0.022	3.022	0.245	0.244	0.244	0.102	4.856	0.111
PGPS_U1	0.814	0.815	0.814	47.723	47.723	44.351	1.000	0.994	134.024	10.887	10.815	10.815	4.544	215.381	4.925
PGPS_U2	0.819	0.820	0.819	48.032	48.032	44.638	1.006	1.000	134.892	10.958	10.885	10.885	4.573	216.777	4.957
CBPSGT3	0.006	0.006	0.006	0.356	0.356	0.331	0.007	0.007	1.000	0.081	0.081	0.081	0.034	1.607	0.037
CEND_U1	0.075	0.075	0.075	4.383	4.383	4.074	0.092	0.091	12.310	1.000	0.993	0.993	0.417	19.783	0.452
CEND_U2	0.075	0.075	0.075	4.413	4.413	4.101	0.092	0.092	12.392	1.007	1.000	1.000	0.420	19.915	0.455
CEND_U3	0.075	0.075	0.075	4.413	4.413	4.101	0.092	0.092	12.392	1.007	1.000	1.000	0.420	19.915	0.455
TMGR_U1	0.179	0.179	0.179	10.502	10.502	9.760	0.220	0.219	29.495	2.396	2.380	2.380	1.000	47.399	1.084
SYPS_U1	0.004	0.004	0.004	0.222	0.222	0.206	0.005	0.005	0.622	0.051	0.050	0.050	0.021	1.000	0.023
PGAU	0.165	0.165	0.165	9.689	9.689	9.005	0.203	0.202	27.212	2.210	2.196	2.196	0.923	43.730	1.000

Table 4.8: Selected pair wise comparison of alternatives for Operating Load

	MPSSGT1	MPSSGT2	MPSSST	PKLG_U1	PKLG_U2	PKLG_U3	PGPS_U1	PGPS_U2	CBPSGT3	CEND_U1	CEND_U2	CEND_U3	TMGR_U1	SYPS_U1	PGAU
MPSSGT1	1.000	1.010	0.964	0.350	0.525	0.392	0.891	0.899	1.022	15.213	15.213	15.213	2.276	5.595	4.961
MPSSGT2	0.991	1.000	0.954	0.347	0.520	0.388	0.883	0.890	1.012	15.069	15.069	15.069	2.255	5.542	4.914
MPSSST	1.038	1.048	1.000	0.363	0.544	0.407	0.925	0.933	1.060	15.788	15.788	15.788	2.362	5.806	5.149
PKLG_U1	2.855	2.883	2.752	1.000	1.498	1.120	2.545	2.567	2.918	43.440	43.440	43.440	6.500	15.976	14.167
PKLG_U2	1.906	1.925	1.837	0.668	1.000	0.748	1.699	1.714	1.948	29.001	29.001	29.001	4.340	10.666	9.458
PKLG_U3	2.550	2.574	2.457	0.893	1.338	1.000	2.273	2.292	2.606	38.795	38.795	38.795	5.805	14.268	12.652
PGPS_U1	1.122	1.133	1.081	0.393	0.588	0.440	1.000	1.008	1.146	17.067	17.067	17.067	2.554	6.277	5.566
PGPS_U2	1.113	1.123	1.072	0.390	0.584	0.436	0.992	1.000	1.137	16.925	16.925	16.925	2.533	6.224	5.520
CBPSGT3	0.979	0.988	0.943	0.343	0.513	0.384	0.872	0.880	1.000	14.888	14.888	14.888	2.228	5.475	4.855
CEND_U1	0.066	0.066	0.063	0.023	0.034	0.026	0.059	0.059	0.067	1.000	1.000	1.000	0.150	0.368	0.326
CEND_U2	0.066	0.066	0.063	0.023	0.034	0.026	0.059	0.059	0.067	1.000	1.000	1.000	0.150	0.368	0.326
CEND_U3	0.066	0.066	0.063	0.023	0.034	0.026	0.059	0.059	0.067	1.000	1.000	1.000	0.150	0.368	0.326
TMGR_U1	0.439	0.443	0.423	0.154	0.230	0.172	0.392	0.395	0.449	6.683	6.683	6.683	1.000	2.458	2.179
SYPS_U1	0.179	0.180	0.172	0.063	0.094	0.070	0.159	0.161	0.183	2.719	2.719	2.719	0.407	1.000	0.887
PGAU	0.202	0.203	0.194	0.071	0.106	0.079	0.180	0.181	0.206	3.066	3.066	3.066	0.459	1.128	1.000

Table 4.9: Selected pair wise comparison of alternatives for Area Power

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